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Piecemeal Reform of Trade and Environmental Policy When Consumption Also Pollutes

Mark R. Metcalfe
United States Forest Service

John C. Beghin
Iowa State University, beghin@iastate.edu

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This paper is a shortened and updated version of Metcalfe and Beghin. It focuses on environmental taxes. Metcalfe and Beghin include the case of environmental quotas. The manuscript has benefited from comments from an anonymous referee and Associate Editor Rick Bond, and from presentations at the IATRC meetings, The AAEA meetings, North Carolina State University and Virginia Polytechnic Institute and State University, and from discussions with David Orden, David Roland-Holst and Dominique van der Mensbrugghe. The usual disclaimer applies.
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Contact: Mark R Metcalfe - metcalfe@fs.fed.us, John C Beghin - beghin@iastate.edu.
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1. Introduction

Most of the analytical literature addressing the coordination of trade and environmental policy reform has focused on production externalities and has not thoroughly investigated the implications of pollution emitted in consumption and the incentives faced by producers to alter the pollution content of their goods released during consumption with the exception of Wang et al., and Ishikawa and Okubo who address the issue in imperfect competitive setting.

We investigate trade and environmental policy reform and coordination in the presence of consumption-induced pollution in a perfectly competitive economy. We focus on domestic externalities where pollution emitted in production and consumption, is a bad for the domestic representative consumer. Producers control the level of pollution emitted during the consumption of their good by altering the input mix in production. An asymmetry arises between exportables and importables as production decisions for exportables are responsive to the foreign taxes on consumption-pollution, unlike the case of importables. The foreign tax is exogenous to the domestic policymaker, and therefore, it is important to distinguish exportables from importables.

We examine policy reform for an economy beset by both tariffs and pollution. A second scenario considers the effects of tariffs and pollution quotas/permits and is reported in a companion paper. In both cases, producers control the level of pollution released through the consumption of their goods, and they face incentives to abate this pollution. We derive sufficient conditions for welfare improvements for coordinated reforms of trade and environmental policies. We identify negative incentive effects that may arise for pollution linked to domestic consumption of exportables. This pollution primarily responds to foreign pollution policies. Trade liberalization may increase the production of exportables that are pollution-intensive in consumption -the pollution content of these goods increases with higher output prices. If the rest of the world does not tighten its policies to discourage its demand for these high-pollution exportables, then it is possible that domestic consumption of these high pollution exportables may release more pollution at home and therefore lead to a decrease in welfare.

The lack of control over foreign policy on pollution calls for an additional domestic policy instrument by the domestic policy maker to control pollution emitted by the consumption of exportables. This finding on the need for either an additional instrument constitutes an important refinement of established recommendations for trade and environment policy coordination. Copeland (1994) and Beghin et al. (1997) show that in general, two domestic instruments, trade and environmental taxes, used jointly, can improve welfare, because they insure that trade does not induce environmental degradation and that environmental taxes do exacerbate the distorting effect of tariffs (See also Turunen-Red and Woodland for similar recommendations in a multilateral context). Metcalfe and Beghin provide a longer treatment of the points made in this manuscript.

2. Tariffs and Pollution Taxes

We distinguish between pollution tax rates in production and consumption. This is equivalent to having two different types of pollution: one type incurred through production and one type through consumption. This separation allows us to investigate the effects of consumption-linked policies. We assume that producers have the ability to alter the intensity of the pollution occurring with the consumption of their output. We assume that consumers are pollution damage-takers with respect to their consumption decisions. Consumers do perceive aggregate

pollution and its negative utility effect, but they do not perceive the impact, through aggregation, of their individual atomistic decisions.

What are the incentives for producers to alter these effluent intensities? They do so to exhaust arbitrage opportunities arising from the lower pollution intensities of domestic goods as opposed to their foreign substitutes. If they adopt a production technology that generates less pollution during consumption than that of their foreign competitors, and if this pollution is taxed both domestically and abroad, then producers can increase their output price up to the point where their price, inclusive of the tax on consumption-induced pollution, is equal to the corresponding price and tax of the foreign competing good.

We denote the per-unit intensity of pollution released in the consumption of goods by α (a vector of intensities for n goods), and the tax on a unit of consumption emissions by s_c. Parameters and variables for the rest-of-the-world are designated by an asterisk. For convenience and without loss of generality, we assume throughout that $\alpha^* > \alpha$ and $s_c \geq s_c^*$. This assumption indicates a technological advantage, possibly driven by regulation, of the domestic country, such as in the case of an OECD-member country, relative to the rest of the world.

Domestic producers as a whole set the prices for their goods in order to capture the potential consumer benefits that would be received through the lower pollution intensity of domestically produced goods. Foreign consumers pay a tax of $s_c^*\alpha^*$ in addition to the world price for a foreign-produced exportable good, but will only have to pay $s_c^*\alpha$ for the exported domestic good. Therefore through arbitrage, all consumers, foreign and domestic, pay an additional $s_c^*(\alpha^*-\alpha)$ per unit of domestic exportables. The pre-tax consumption price at which producers of exportables are able to sell their products is: $P_p^e=Q^e+\tau^e+s_c^{*\prime}(\alpha^{e*}-\alpha^e)$, where P_p is the vector of prices received by the producer, Q is the vector of exogenously determined world prices, τ is the per-unit vector of domestic export taxes/subsidies ($\tau^e>0$ represents an export subsidy), and superscript e designates exportable goods.

Similar intuition applied to the import market and domestic consumers provides the producer price of imports: $P_p^m=Q^m+\tau^m+s_c'(\alpha^{m*}-\alpha^m)$, where τ^m is the per unit vector of domestic import taxes/subsidies ($\tau^m > 0$ is an import tax) and superscript m represents importable goods.

The total price paid by consumers for a good is equal to the producer price plus the amount of tax paid on consumption pollution. Therefore, the domestic consumer price for exportables is: $P_c^e=Q^e+\tau^e+s_c^{*\prime}(\alpha^{e*}-\alpha^e)+s_c'\alpha^e$, where P_c is the vector of consumer prices. A domestically produced importable will have its consumer price equal to its domestic producer price, $Q^m+\tau^m+s_c'(\alpha^{m*}-\alpha^m)$, plus a tax of $s_c'\alpha^m$. A foreign-produced importable will have a domestic consumer price equal to the foreign producer price after the border of $Q^m+\tau^m$ plus a tax of $s_c'\alpha^{m*}$. Consumers must be indifferent between the two goods in equilibrium, hence $P_c^m=Q^m+\tau^m+s_c'\alpha^{m*}$.

We use a dual treatment of a perfectly competitive and open economy (Copeland, 1994). We consider the case of n goods, each containing one production pollutant and one consumption pollutant, which are taxed. A revenue function summarizes production decisions in competitive markets and is characterized as: $R(P_p^m(\tau^m, s_c), P_p^e(\tau^e, s_c^*), s_c, s_c^*, s_\gamma, v) = \max_{(x,A,\Gamma)}\{[(Q^m+\tau^m+s_c'\alpha^{m*})'x^m-s_c'A^m-s_\gamma'\Gamma^m] + [(Q^e+\tau^e+s_c^{*\prime}\alpha^{e*})'x^e-s_c^{*\prime}A^e-s_\gamma'\Gamma^e] \mid (x, A, \text{and } \Gamma) \text{ feasible given inputs } v\}$, where x is the vector of production; A is total pollution generated through consumption of domestically produced products, $A = \alpha'x$; γ is the vector of per-unit production pollution intensity for n goods, s_γ is the per-unit production pollution tax, Γ is total pollution generated through production of domestically produced products, $\Gamma=\gamma'x$. The revenue function incorporates

both a direct and an indirect feedback effect on the revenues of importables caused by an exogenous change in the tax level s_c. These two effects reflect producers' adjustment of the levels of the consumption effluent rate with a change in s_c, as a high α adversely affects their abilities to set higher prices through arbitrage. The direct effect is the change in R given constant prices and output, while the indirect feedback involves an output effect occurring from the change in producer price.

The revenue function satisfies all the usual properties. Applying the envelope theorem to *R*, the following results are obtained: $R_{p^m}=x^m$; $R_{p^{ex}}=x^e$; R_{pp} is the Hessian of price elasticities for output x; $R_{s_\gamma}=-\Gamma$; $R_{s_c}=x^{m\prime}\alpha^{m*}-A^m|_p$, which is the consumption pollution savings on all importables produced domestically as compared to if they had all been imported; $R_{s_cs_c}$ is the response of this savings to a change in consumption pollution tax and it is positive semi-definite; R_{s_cp} is minus the cross-price response of this difference to a change in output prices and is positive semi-definite; and R_{ps_c} is the response of output to a change in the consumption pollution tax. The usual symmetry holds, $R_{ps_c}{}'=R_{s_cp}$.

The expenditure function is: $E(P_c^m(\tau^m,s_c),P_c^e(\tau^e,s_c,s_c^*),T,U_o) = \min_{(c)}\{(Q^m+\tau^m+s_c'\alpha^{m*})'c^m+(Q^e+\tau^e+s_c^{*\prime}(\alpha^{e*}-\alpha^e)+s_c'\alpha^e)'c^e|\ U\geq U_o\}$, where c is the vector of consumption, and $U\geq U_0$ is the utility constraint. Envelope theorem results provide $E_{p^m}=c^m$, $E_{p^{ex}}=c^e$, and $E_{s_c}=c^{m\prime}\alpha^{m*}+c^{e\prime}\alpha^e$. The latter is the consumption pollution if all importables consumed were imported plus the pollution emitted by the consumption of exportables; $E_{s_cs_c}$ is the scalar response of this pollution to a change in consumption pollution tax and is negative; E_{s_cp} is the cross-price response of this total pollution to a change in consumer prices; E_{pp} is the Hessian of price responses of consumption; E_{ps_c} is the cross-price response of consumption to a change in the consumption pollution tax; and again by symmetry, $E_{ps_c}{}'=E_{s_cp}$. E_U is the inverse of the marginal utility of income.

The pollution generated in domestic consumption T_{cons} is $T_{cons} = E_{s_c} - R_{s_c}$. Total pollution T is constructed as a measure of total domestic pollution in the economy emitted through both consumption and production; $T \equiv T_{cons}+ T_{prod}$; where T_{prod} is production pollution and is equal to $-R_{s_\gamma}$. Therefore, $T= E_{s_c} - R_{s_c} - R_{s_\gamma}$, or $T= c^{m\prime}\alpha^{m*}+c^{e\prime}\alpha^e - x^{m\prime}(\alpha^{m*}-\alpha^m) +\Gamma$. This definition could accommodate asymmetric marginal impacts on utility for the two types of pollution by weighting T_{cons} and T_{prod} differently. As mentioned above, atomistic consumers are marginal damage-takers and this is represented by restricting the change in expenditure with respect to total pollution, E_T, to be a constant to the individual agent. This assumption allows us to treat otherwise homogenous domestic and foreign goods with different α and α^*, as perfect substitutes. That is, the individual consumer does not value the difference in pollution intensities, except for their tax incidence on her/his expenditure.

The equilibrium of the economy is represented by the following equations which equate expenditures and revenues and define total pollution and net-imports:

(1) $E=R+\tau' M+s_c'T_{cons}-s_\gamma'T_{prod}$,

(2) $T\equiv T_{cons}+T_{prod}$, and (3) $M=E_p-R_p$.

Totally differentiating equation (1) provides the following fundamental relationships between welfare, trade, and pollution:

(4) $E_U dU=\tau' dM+(s_c-E_T)' dT_{cons}+(s_\gamma-E_T)' dT_{prod}.-E_{p^e}(s_c-s_c^*)d\alpha^e$.

Distortions in the economy are imposed through the implementation of tariffs and non-optimal effluent taxes, as well as by the difference between the domestic and foreign effluent taxes on consumption. The distortions caused through non-optimal taxes are separated into consumption and production pollution effects on welfare. equation (4) shows the negative welfare effect of increases in exportable consumption pollution intensity. Increases in α^e cause an unambiguous welfare loss.

The overall effect of pollution in the model is determined through differentiation of (2):

(5) $dT=(dT/ds_c|_\alpha)ds_c+(dT/ds_\gamma)ds_\gamma+(dT/dP)d\tau+E_{s_cU}\,dU+E_{s_cT}\,dT+E_{s_cp^e}(s_c-s_c^*)d\alpha^e$.

Abatement in total pollution is a function of six components: effluent taxes in consumption and production, tariffs, welfare, changes in the marginal damage of pollution, and the pollution intensity of exportables in consumption. Therefore, pollution is dependent on exogenous policy changes as well as on a real income effect, a feedback effect of the marginal damage of pollution, and the pollution intensities of exportables. The cross-price effect of α^e on total pollution reflects its dependence on foreign environmental policies (s_c^*), tariff reform, and the available arbitrage opportunities of producers reacting to this foreign tax.

In a similar fashion, the effects on net imports are found through differentiation of (3):

(6) $dM=(dM/ds_c)ds_c-R_{ps_\gamma}\,ds_\gamma+(dM/dP)d\tau+E_{pU}\,dU+E_{pT}\,dT+E_{pp}(s_c-s_c^*)\,d\alpha^e$.

In the same way, net imports are dependent on exogenous policy changes, a real income effect, changes in the marginal damage of pollution, and the effect of α^e on the consumer price of exportables again through producer arbitrage.

Changes in the policy instruments τ, s_c, and s_γ and their effect on the consumption pollution intensities of exportables are best understood by remembering that $\alpha_i=A^i/x^i$, which reflects decisions by producers as summarized by the revenue function. The changes are represented by:

(7) $d\alpha^e=(d\alpha^e/dP)d\tau+(d\alpha^e/ds_\gamma)ds_\gamma+[d\alpha^e/ds_c|_p+(d\alpha^e/dP)(dP/ds_c)]ds_c$.

The endogenous response of α^e to changes in s_c contains both the direct and indirect effects from the revenue function.

3. Coordinated Policy Reforms with Pollution Taxes

Substituting equations (5) and (6) into equation (4) provides the comparative-statics of joint trade and environmental piecemeal reform in terms of the policy instruments and the feedback effect on α^e. We obtain:

(8) $DdU = \{\tau' dM/dP + (s_c-E_T^{ge})\,dT_{cons}/dP + (s_\gamma-E_T^{ge})\,dT_{prod}/dP\}d\tau$
$+ \{\tau'\, dM/ds_c + (s_c-E_T^{ge})\,dT_{cons}/ds_c|_\alpha + (s_\gamma-E_T^{ge})\,dT_{prod}/ds_c|_\alpha\}ds_c$
$+ \{\tau' dM/ds_\gamma + (s_c-E_T^{ge})\,dT_{cons}/ds_\gamma|_\alpha + (s_\gamma-E_T^{ge})\,dT_{prod}/ds_\gamma|_\alpha\}ds_\gamma - \{C\}d\alpha^e$,

with $D=E_U-\tau' E_{pU}-s_c\,E_{s_cU}+E_T^{ge}\,E_{s_cU}>0$ denoting the general equilibrium inverse of marginal utility of income, $C = B+E_T^{ge}\,E_{s_cp^e}(s_c-s_c^*)>0$ denoting the general equilibrium consumption E_{p^e} times $(s_c-s_c^*)$, $B=(E_{p^e}-\tau' E_{pp^e}-s_c\,E_{s_cp^e})(s_c-s_c^*)>0$, and with $E_T^{ge}=(E_T-\tau' E_{pT}-s_c\,E_{s_cT})(1-E_{s_cT})^{-1}$ denoting the general equilibrium marginal damage of pollution. We did not substitute in the endogenous change $d\alpha^e$ from equation (7) because the current form of (8) decomposes the welfare effects of the coordinated reform into a positive effect holding α^e constant and an ambiguous component due to the feedback on $d\alpha^e$.

Establishing unambiguous results for coordinated trade liberalization and environmental policy reforms in the presence of $d\alpha^e$ requires either an additional policy instrument or more structure to identify special cases. We do this in sequence next.

We consider the following joint reform: trade liberalization achieved by a proportional decrease of tariff distortions ($d\tau=-k\tau$) accompanied by a proportional decrease of pollution distortions $ds_c=-k(s_c-E_T^{ge})$ and $ds_\gamma=-k(s_\gamma-E_T^{ge})$, and with the imposition of a process standard or a cap on α^e set at the just binding pre-reform level and which insures that α^e does not increase with the reform of tariffs and pollution taxes. These joint reforms correspond to the coordinated policies examined in Copeland (1994) and Beghin et al. (1997). The tariff and tax instruments alone unambiguously increase welfare, except for their potentially "perverse" feedback effect on α^e that could increase pollution and therefore decrease welfare. The process standard fixing pollution emitted in consumption on exportables (α^0), then caps the potential feedback effect of tariff and tax changes on these pollution intensities; it insures that the coordinated reform is welfare-improving (i.e., a sufficient condition is $d\alpha^e \leq 0$). The foreign effluent tax, s_c^*, has a strong negative influence on α^e, but it is exogenous to the domestic policymaker. We summarize this discussion formally:

Result 1. *Under the assumptions of section 2, a coordinated proportional policy reform: $d\tau=-k\tau$, $ds_c=-k(s_c-E_T^{ge})$, $ds_\gamma=-k(s_\gamma-E_T^{ge})$, accompanied by a just-binding standard on exportable pollution intensity: $\alpha^e \leq \alpha^0$, is welfare improving.*

The standard, which may be non-optimal (marginal damage of pollution and shadow price of the standard may not be equal), improves welfare when it is set at a just binding level. The use of a standard in our analysis is reminiscent of the use of a standard in the case of transboundary pollution analyzed by Copeland (1993). Our case differs because we analyze a domestic externality problem and tariffs are reduced towards their first best levels.

The third instrument imposed on α^e is not necessary in an important special case. If s_c^* and s_c are equal before the reform or do not exist, then the coordinated reform of tariffs and taxes has no feedback on intensities α^e and is welfare improving. We summarize this case in the following result.

Result 2. *Under the assumptions of model section 2, if pollution is not regulated before the policy reform ($s_c^*=s_c=0$) or trading partners have harmonized environmental taxes ($s_c^*=s_c$), then a coordinated proportional reform: $d\tau=-k\tau$, $ds_c=-k(s_c-E_T^{ge})$, $ds_\gamma=-k(s_\gamma-E_T^{ge})$, is welfare improving.*

4. Concluding Remarks

We derived sufficient conditions for welfare-improving piecemeal trade and environmental policy reforms in the presence of both production and consumption pollution, and when producers respond to domestic and foreign effluent taxes on consumption-induced pollution. An additional policy instrument is required to cap pollution intensities of exportables, such as a standard capping the intensity of consumption pollution.

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